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Ionospheric Model Assessment Using TRANSIT Data

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13. ABSTRACT (Maximum 200 words)

Total Electron Content (TEC) measurements derived from observation of polar-orbiting TRANSIT satellites have been incorporated into an assessment of the Bent ionospheric model, as implemented for the PAVPAW program utilized by the USAF Environmental Technical Applications Center (ETAC). Both temporal and spatial assessments of the ionospheric model have been performed. By suitable adaptation of the programs developed for this assessment, similar assessments of other ionospheric models could be performed.

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I. INTRODUCTION

Total Electron Content (TEC) measurements derived from observations of polar-orbiting TRANSIT satellites have been incorporated into an assessment of the Bent ionospheric model, as implemented for the PAVPAW program utilized by the USAF Environmental Technical Applications Center (ETAC). Both temporal and spatial assessments of the ionospheric model have been performed, for a span of approximately 30 days of data in September and October of 1989. By suitable adaptation of the programs developed for this assessment, similar assessments of other ionospheric models could be performed.

A. TRANSIT Data

The raw TRANSIT satellite observations were performed and processed in Great Britain, using Global Positioning System (GPS) or foF2 measurements at nearby times and viewing directions to provide reference calibration values. The results are presented as local vertical TEC values, associated with the latitude and longitude of the ionospheric penetration point (IPP) for a designated ionospheric reference altitude of 350 km. The date and Greenwich time of the first sample are also recorded. The sampling interval is 5 seconds, and the typical time span of an individual TRANSIT satellite observation (a TRANSIT "pass") is approximately 13 minutes. The data tabulations are sent from Great Britain to Hanscom Air Force Base, Massachusetts, using an electronic mail network.

B. ETAC Model

The PAVPAW program, implementing the Bent ionospheric model[1], has been standardly used to provide path-length corrections associated with TEC variations, on a monthly basis. In addition to a set of parameters intrinsic to the model, two environmental parameters required to determine the model results are the sunspot number and solar flux. These environmental parameters are specified for the fifteenth day of each respective calendar month.

The path-length corrections for designated viewing directions were the original quantities generated by the PAVPAW program, but for comparison with the TRANSIT data, the program was modified to operate as a subroutine, returning the TEC for the specified slant path. The following quantities are provided as arguments

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[1] Llewellyn, S.K., and Bent, R.B. (1973) Documentation and Description of the Bent Ionospheric Model, AFCRL-TR-73-0657, AD772733

to the subroutine:

- observation site name;
- reference transmission frequency;
- observation site latitude (positive North);
- observation site longitude (positive East);
- year, month, and day of observation;
- time of day of observation;
- mean sunspot number;
- mean solar flux;
- elevation angle for viewing direction;
- azimuthal angle for viewing direction (positive counterclockwise from North).

II. DATA ANALYSIS

A. Statistics Tabulation

For use of the TRANSIT data in a statistical analysis, the individual passes are divided into two-minute segments, with one minute of time overlap between successive segments. Each individual vertical TEC measurement is converted to a corresponding slant-path TEC measurement, using the relative positions of the nominal observing station and IPP to calculate the elevation angle for the viewing direction and the corresponding slant-path correction factor. It should be noted that the nominal observing station (York, England) is not the actual observing station (Lerwick, Scotland), but the ionospheric conditions at the nominal observing station are the ones desired for the assessment. This translation biases the sampling of available TRANSIT data to the northern segment of the sky, as illustrated in Figure 1. This effect can also be discerned in the azimuthal selection groups for the statistical samples.

Two-minute averages of the TRANSIT slant-path TEC values are computed and stored in the statistics database. Additionally, the standard deviation of the TRANSIT vertical TEC values for the same two-minute period is computed and stored, as a measure of the transverse TEC variation, avoiding the geometrical path-length variation with elevation angle. Portions of the TRANSIT pass that are below 5° elevation are not utilized for the two-minute averages, and trailing portions of the TRANSIT passes that are less than two minutes long are also excluded from the statistical determinations.

Based on model and site-dependent parameters provided, and on the time, elevation, and azimuth of the midpoint of the two-minute TRANSIT data segment, the ETAC model slant-path TEC is calculated and stored with the corresponding TRANSIT slant-path TEC value in the statistics database. The date, time, elevation, and azimuth used for the model calculation are also stored.

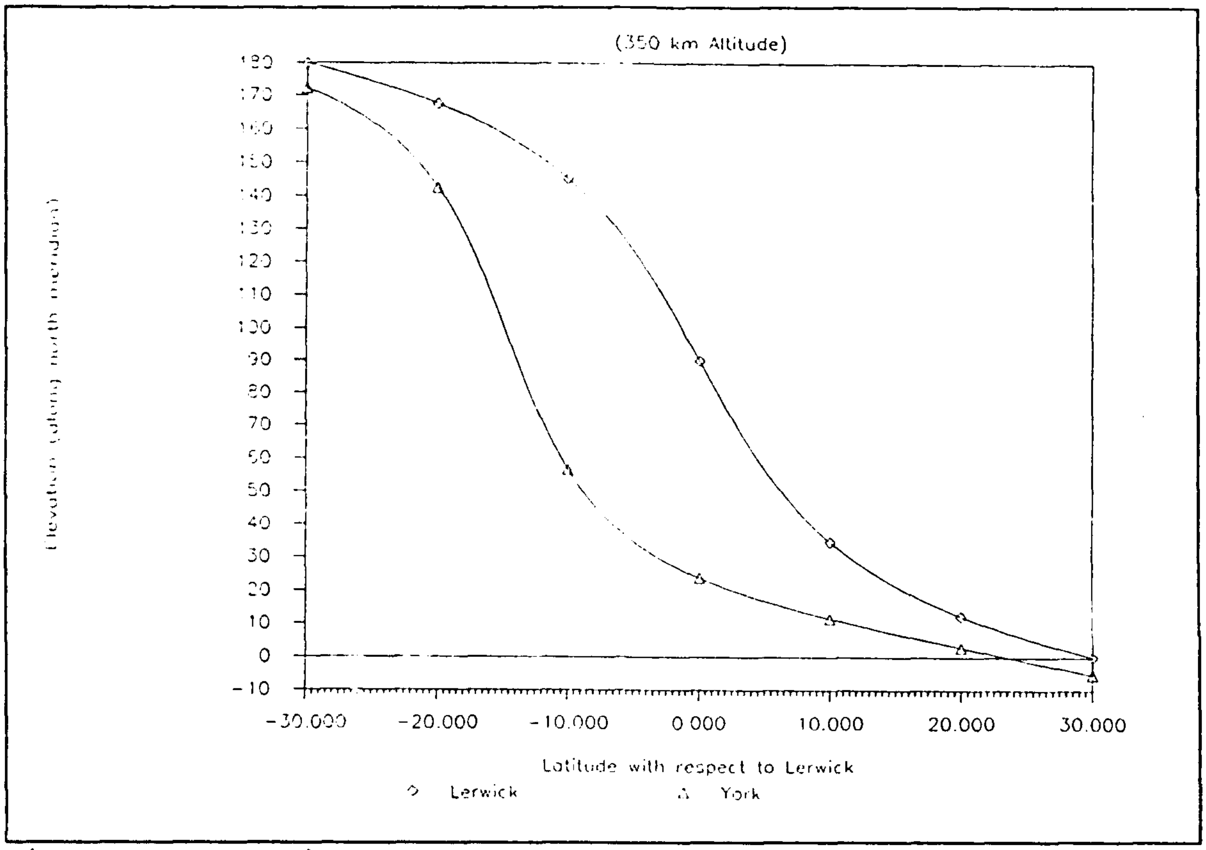

Figure 1. Elevation Angles to Common Ionospheric Penetration Point

B. Statistical Database Format

The data structure for storage of these quantities is a FORTRAN direct-access file, with seven-word data records defined in the following manner:

JDate = Julian date of data (yyddd) [I*4]
Time = Universal time for midpoint of data segment, in seconds [I*4]
Elev = elevation, in degrees, for line-of-sight at midpoint of segment [R*4]
Azim = azimuth, in degrees counterclockwise from North, for line-of-sight at midpoint of segment [R*4]
TECX = average slant-path TEC, in TEC units, from TRANSIT [R*4]
TECM = midpoint slant-path TEC, in TEC units, from ETAC model [R*4]
SDvX = standard deviation of vertical TRANSIT TEC values about mean vertical TRANSIT TEC value [R*4]

The FORTRAN variable types specified for each variable are I for INTEGER and R for REAL (floating-point), with size allocations specified in bytes. There is a separate record for each two-

minute TRANSIT segment.

There is a separate header record for the database, with the same length in bytes as an individual data record, but with a different content, defined as follows:

NRec = number of data records in file (updated for each record added) [I*4]
Site = site name (truncated to four characters) [C*4]
SLat = site latitude (positive North) [R*4]
SLon = site longitude (positive East) [R*4]
Three blank words [I*4]

The variable type C specified above is a FORTRAN CHARACTER type, four bytes long. The number of records is stored as a header variable to allow a previously created database to be augmented by subsequent TRANSIT pass data, and for reference in processing the statistics database by additional programs.

C. Model Adjustment Assessment

An alternative statistics database in the same format as the original statistics database can be generated from the original database, as part of an assessment of the model adjustment procedure which has been implemented at observation sites. In the model adjustment procedure, absolute measurements of slant-path TEC, using available reference satellites, are employed to re-scale the slant-path TEC values predicted by the model, for a designated period of time after the satellite observations are performed. Once the designated time interval expires, model TEC values are no longer re-scaled, until another absolute TEC reference measurement can be performed.

A program has been developed to emulate this process, using the original TEC statistics database. The designated time interval (the "back-referenced" time) can be provided to the program as an operating value. For sequential TRANSIT passes stored in the database, the average of the ratio of each TRANSIT slant-path TEC value to the corresponding ETAC model slant-path TEC value over the entire earlier pass is used as the update factor for each ETAC slant-path TEC value for the later pass, unless the "back-referenced" time limit is exceeded, in which case the entire later pass is excluded from the alternative database. For passes that are modified, only the ETAC model value is changed, with the revised value being stored at the same relative record position as the original ETAC model value. Thus, all analysis programs developed for evaluation of the original statistics database can be utilized in evaluating the "back-referenced" database.

D. Error Overview Representation

A simple, but useful, assessment of the ETAC model accuracy is presented by a plot of the ETAC slant-path TEC values against the corresponding TRANSIT slant-path TEC values. (See Figure 2.)

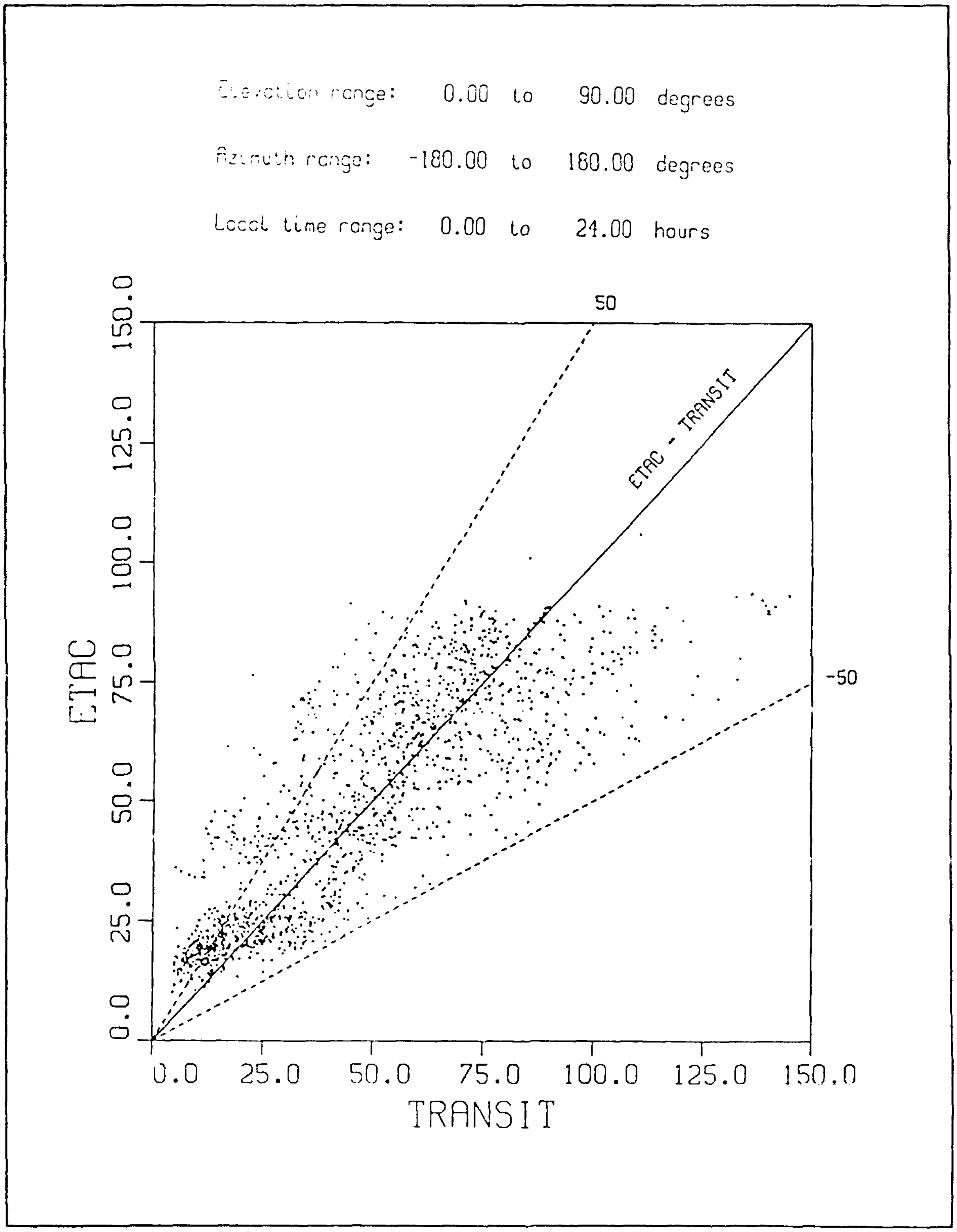

Figure 2. Comparison of ETAC Model to TRANSIT Data

The reference lines bracketing the diagonal line are indicators of relative fractional error for the model with respect to the measurements. The database records utilized in this comparison can be selected based on any combination of elevation, azimuth, and local time. Principal selection sets have been chosen based on the following domain boundaries:

Elevation: (0°, 20°, 42° (to 90°))
Azimuth: (-135°, -45°, 45°, 135° (to 225°))
Local time: (3^h, 9^h, 15^h, 21^h (to 27^h))

The elevation domains were specified on a nearly equal-area basis, while the azimuth domains were chosen to be centered on the principal compass directions: East, North, West, and South. The local time domains correspond roughly to morning, noon, evening, and midnight, and match the basic phases of the diurnal TEC variation.

E. Detailed Error Assessment

A more quantitative assessment of the relative model error is provided by a set of histograms, which display the relative frequency of occurrence per unit percentage error versus the amount of error. (See Figure 3.) As with the overview plots, the database records displayed for this assessment can be selected based on any combination of elevation, azimuth, and local time, and the principal selection sets have been chosen based on the same domains as for the overview plots. The error bins can be specified arbitrarily, and, as illustrated, the bin widths need not be identical. However, the use of a relative occurrence per unit error allows comparability between bins of different widths, either on a given histogram or between different histogram sets.

The preliminary set of histogram bins is specified according to the following lower limits for the bin ranges:

Percent error: (-100%, -75%, -50%, -40%, -30%, -20%, -10%, 0%, 10%, 20%, 30%, 40%, 50%, 75%, 100%)

To avoid potential optimistic misinterpretations of the tabulations, error values that lie beyond the range spanned by the bins are tabulated into the appropriate bin at each margin of the spanned range.

III. DATA DISPLAY CAPABILITIES

As part of the data processing, evaluations are performed on the raw TRANSIT vertical TEC values, distinct from comparisons to any models. The displays produced for these evaluations are of use in understanding the diurnal and convectional variations of the ionospheric charge density.

TEC profile plots, for vertical TEC versus latitude, are generated for each TRANSIT pass in the early stages of the data

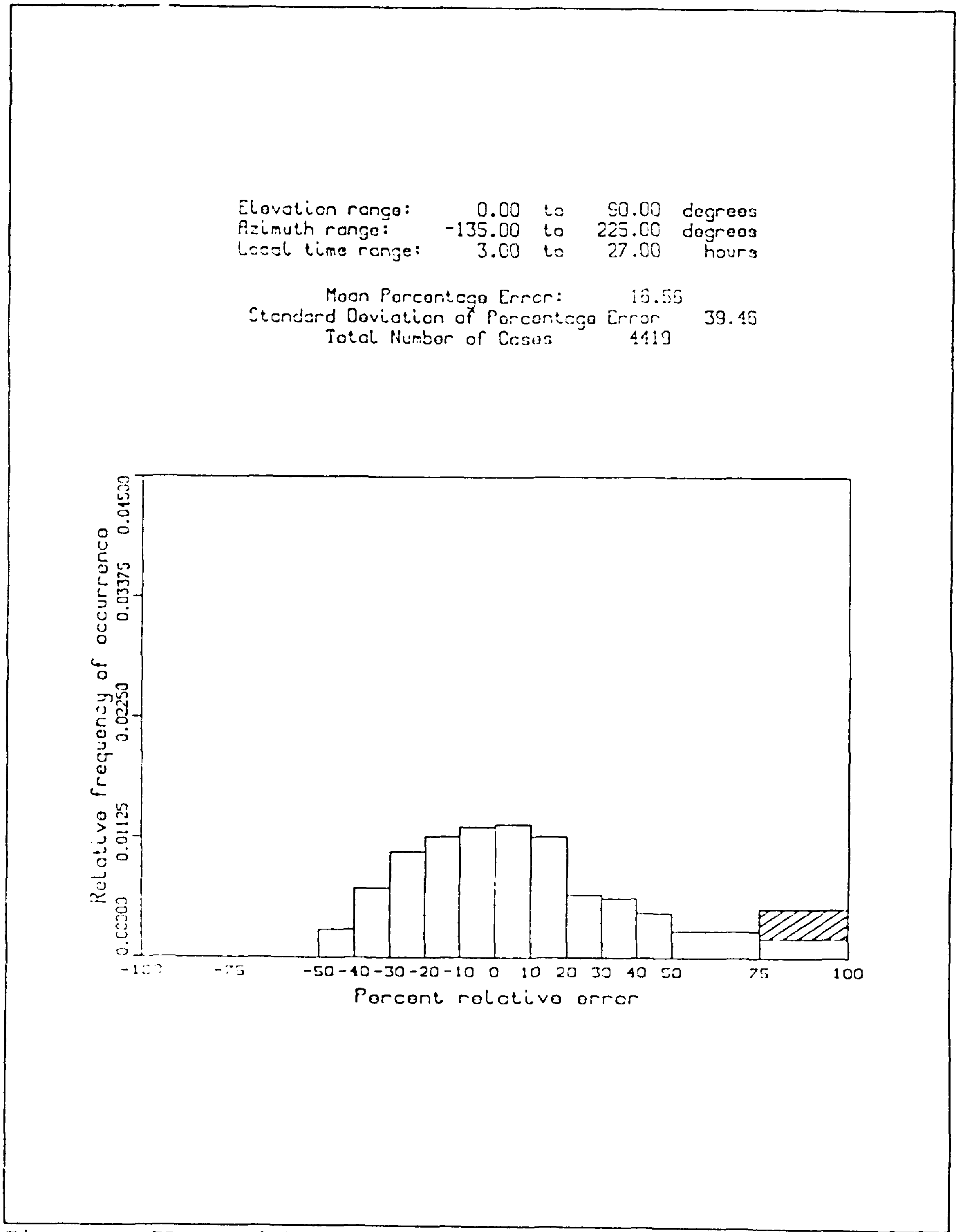

Figure 3. ETAC Model Evaluation (TRANSIT Data)

processing. These plots show the detailed variations in TEC, and provide a succinct summary of the raw data files. (See Figure 4.)

For days on which a reasonable number of TRANSIT passes were recorded, the overall coverage of the composite passes can be displayed on a projection plot of the northern hemisphere. Because the TRANSIT passes are recorded from a geographically fixed site, the azimuthal variable in such a representation is local time instead of longitude. Further information about the vertical TEC profiles is displayed on this plot by encoding the TEC values as alphabetic characters. (See Figure 5.) This format was originally developed as an aid in developing trough models from the TRANSIT data.

If the coverage provided by TRANSIT passes on a given day is adequate, a three-dimensional display of vertical TEC versus local time and magnetic latitude can be produced, with only minimal distortion produced by the interpolation between TRANSIT passes. Three standard perspectives are generated, for better evaluation of the ionospheric features. (See Figure 6.)

IV. SOFTWARE DESCRIPTION

The software routines used to process, analyze, and display the TRANSIT and ETAC data are described in an order appropriate to the sequence that they would normally be used for processing a 30-day segment of TRANSIT data. All programs were developed for the local VAX/VMS system configuration, with the DISSPLA™ and NCAR (National Center for Atmospheric Research) graphics support software and laser plotter devices. Some VAX extensions to FORTRAN-77 have also been incorporated into the programs, where this proved advantageous.

The following descriptions indicate the input and output data items, including specifications provided by the user. For FORTRAN NAMELIST items, internal program default values are allowed for the associated variables, and these are indicated in parentheses before the variable descriptions.

A. SEGMENT

The SEGMENT program extracts the individual TRANSIT passes from the composite files which are transmitted from Great Britain as electronic mail messages. Provisions are incorporated in the program to remove the routing header for each mail message file.

The files generated in the segmentation process are named according to the date and time appearing in the header for each pass. The filename portion, in the VAX/VMS name designation, consists of the date of the pass, in the same 'yymmdd' format for year, month, and day as it appears in the file header. The

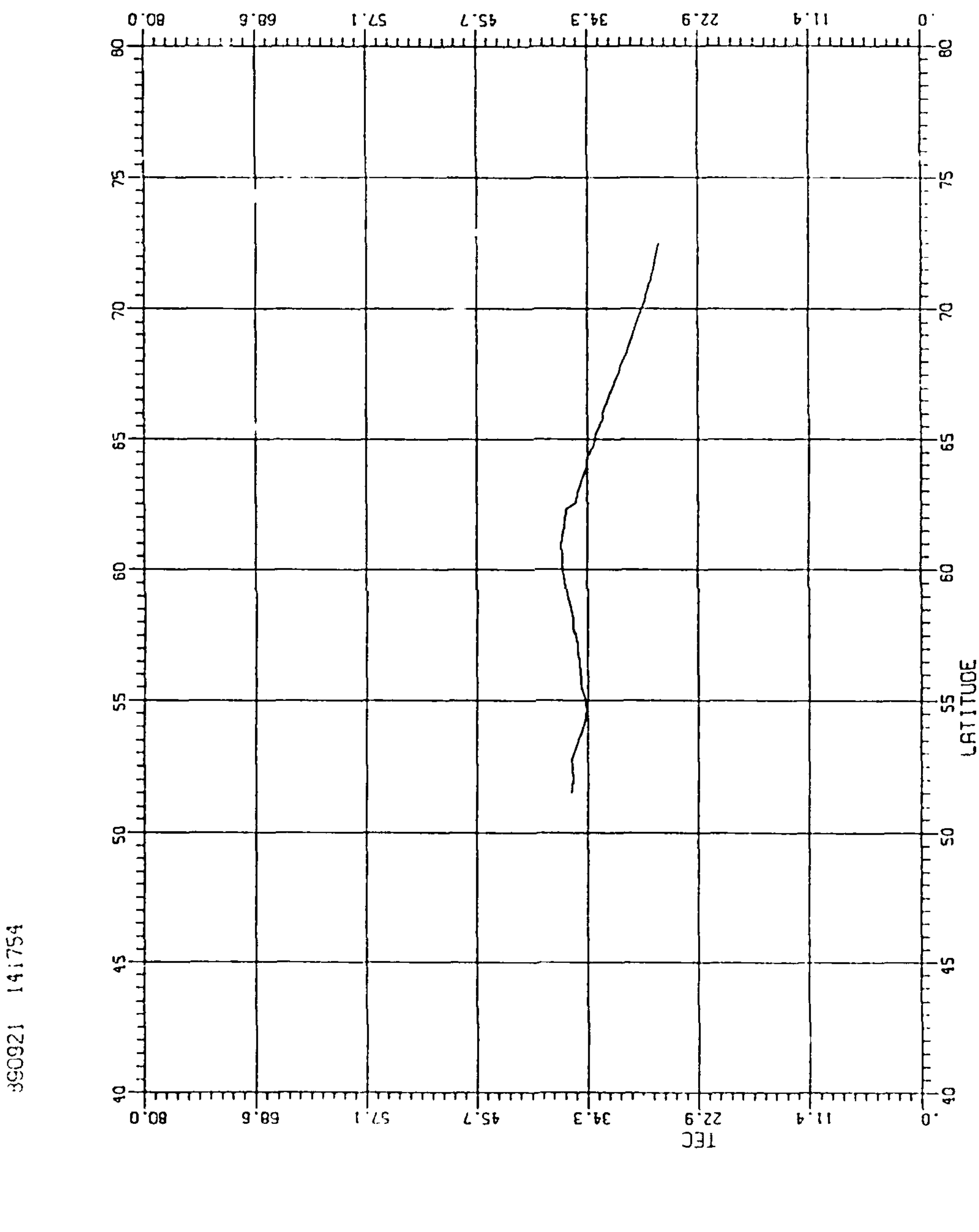

Figure 4. Vertical TEC Profile for TRANSIT Pass

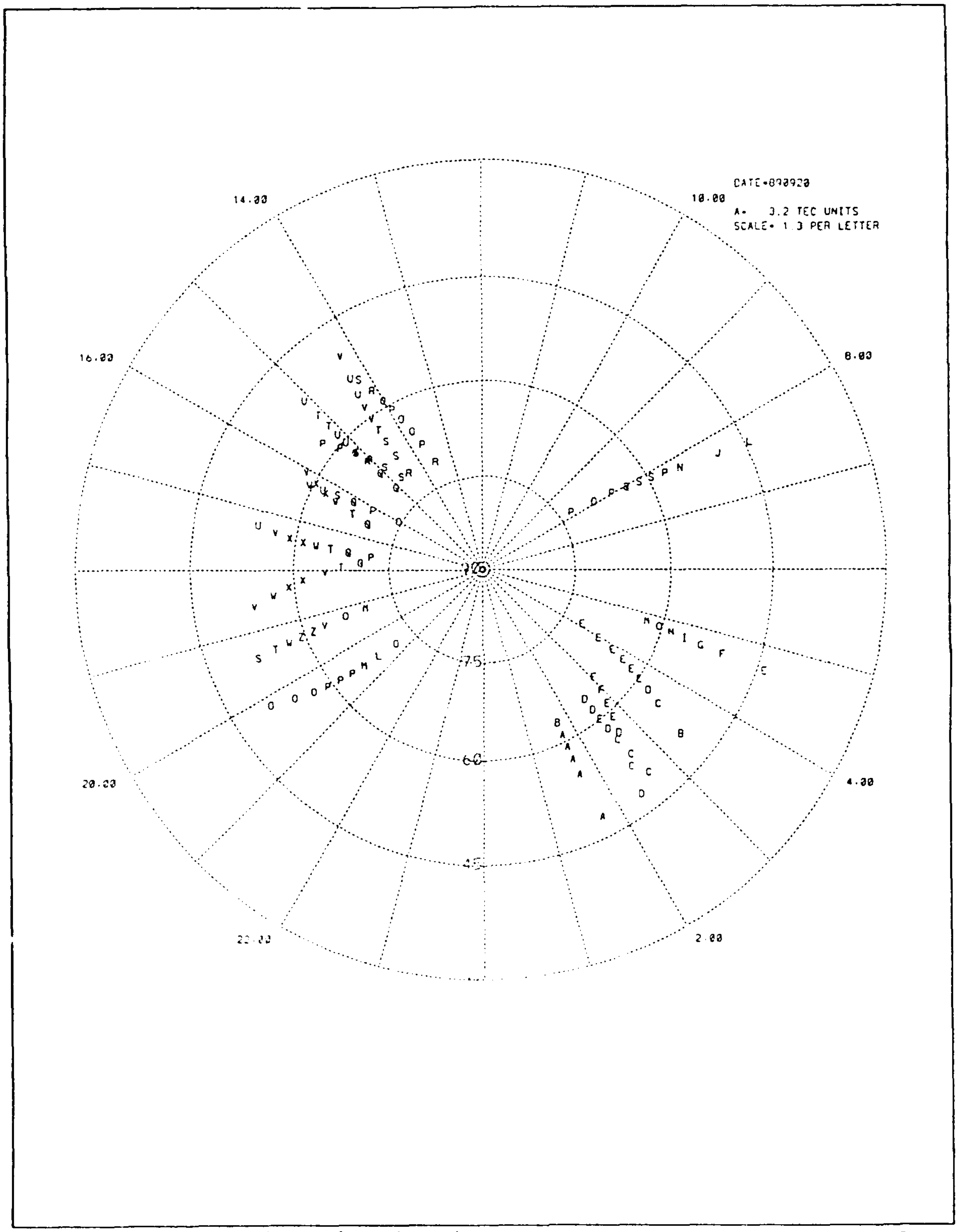

Figure 5. Local Time Distribution of TRANSIT Passes: 20-Sep-89

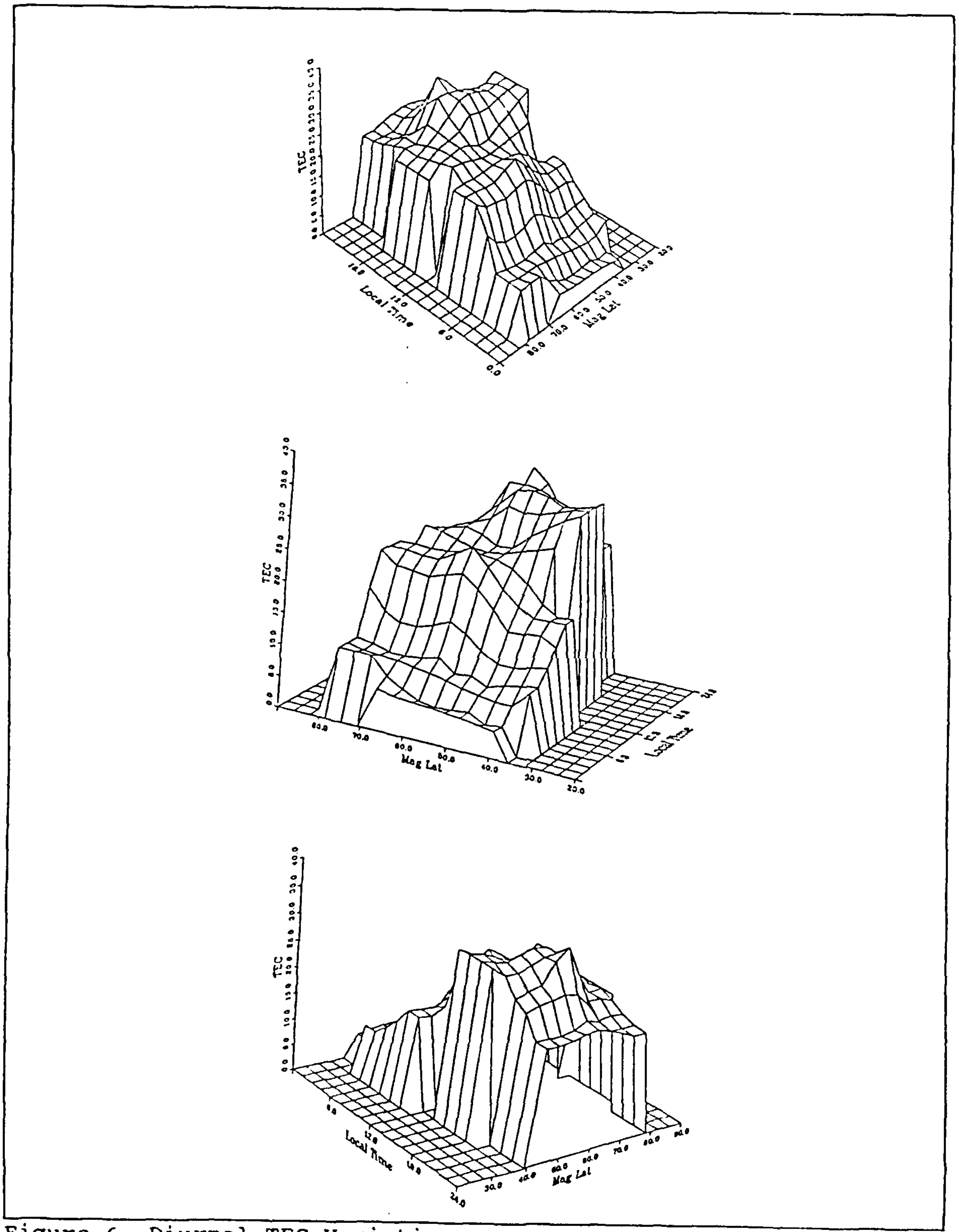

Figure 6. Diurnal TEC Variation

initial time for the pass samples is encoded in the extension, using an alphabetic character A-X to represent the hour, and displaying the minutes as a direct numerical value 00-59. These data file names are also listed to a separate file, to serve as a basis for developing program inputs for subsequent processing.

Program: SEGMENT

Input:
- SYS$INPUT: Name of composite TRANSIT file (20 characters or less); e.g. 890920.GRP;
- Unit 1: Composite TRANSIT file named above;

Output:
- Unit 2: Individual TRANSIT pass files, named by date and time;
- Unit 4: List of TRANSIT pass files generated, into file with first seven characters of composite file name and REF extension;

B. PLTDATA

The PLTDATA program generates a plot of vertical TEC versus latitude, referred to as a TEC profile, for each TRANSIT pass file supplied. The plot ranges in latitude and TEC can be specified by the user, or can be left to be determined by the program, based on the ranges of the acquired data for the pass. Standard ranges are [40°, 80°] latitude and [0, 80] TEC units.

Provisions are included in PLTDATA to decimate the pass data before plotting, and to provide a caption for the plot.

Program: PLTDATA

Input:
- SYS$INPUT:
  - Namelist PLTSPC
    - XMIN = (0) lower limit of latitude range for plot (degrees);
    - XMAX = (0) upper limit of latitude range for plot (degrees);
    - YMIN = (0) lower limit of TEC range for plot (TEC units);
    - YMAX = (0) upper limit of TEC range for plot (TEC units);
    - LOGX = (0) flag to indicate whether abscissa is linear (0) or logarithmic (1);
    - LOGY = (0) flag to indicate whether ordinate is linear (0) or logarithmic (1);
    - NDIVX = (10) number of major divisions on abscissa;

NDIVY = (10) number of major divisions on ordinate;
NSUBX = number of subdivision tick marks for abscissa;
NSUBY = number of subdivision tick marks for ordinate;
ILINE = (1) flag to indicate pointwise (0) or line (1) plot;
IDATE = (0) flag for plot generation date in caption;
PTSIZE = (0.001) size of points to be plotted (inches);
FMTX = optional format specification for abscissa numerical labels;
NCHX = number of characters in optional abscissa label format;
FMTY = optional format specification for ordinate numerical labels;
NCHY = number of characters in optional ordinate label format;
BTM_MAX = (0.95) scale factor for abscissa frame dimension;
LFT_MAX = (0.90) scale factor for ordinate frame dimension;
EPSX = (0.0) tolerance for plotting points outside of plot frame (abscissa units);
EPSY = (0.0) tolerance for plotting points outside of plot frame (ordinate units);
ID_CURVS = flag to plot identifying symbols on data curves;

Namelist USRSP

TECFIL = name of TRANSIT pass file to be plotted;
FITFIL = name of file for TEC profile fit coefficients (not used);
ALATLO = (20.0) lower limit of latitude range for plot of fit to TEC profile (not used);
ALATHI = (60.0) upper limit of latitude range for plot of fit to TEC profile (not used);
IDECIM = decimation factor for TRANSIT data being plotted;
TITLE = caption for plot;

Unit 1: TRANSIT file named above (TECFIL);
Unit 2: Fit coefficient file named above (FITFIL) (not used);

Output:

Metacode file for NCAR metacode translato. ;

C. TRANSIT_INFO

The TRANSIT_INFO program provides a summary listing of the beginning and ending times, latitudes, and longitudes for the individual TRANSIT passes. (See Table I.)

Program: TRANSIT_INFO

Input:
- Unit 1: (FILEIN.DAT) Names of TRANSIT pass files to be tabulated;
- Unit 2: Individual TRANSIT pass files, as listed in FILEIN.DAT;

Output:
- Unit 10: (FOR010.DAT) Summary list of TRANSIT passes, with date, beginning time, latitude, and longitude, and ending time, latitude, and longitude for each pass;

D. TECSTAT

The TECSTAT program performs the segmentation of the TRANSIT passes, converts the vertical TRANSIT TEC values to slant-path TEC values, and invokes the ETAC model to calculate the corresponding prediction for the slant-path TEC value. These values and relevant auxiliary parameters are then stored in a database file for further analysis.

Program: TECSTAT

Input:
- SYS$INPUT: Namelist USRSPC
  - SITE = four-character observation site identifier;
  - INLIST = filename of list of TRANSIT pass files to be processed, with ETAC model parameters to be associated with each pass;
  - OUTFIL = filename of statistics database to be created or augmented;
  - OBSLAT = observation site latitude (positive North);
  - OBSLON = observation site longitude (positive East);
  - LLTFIL = character flag for requesting an auxiliary listing (value = "Y" for listing);
- Unit 1: (filename specified by INLIST) Names of TRANSIT pass files to be processed, with ETAC parameters for each pass;
- Unit 3: Individual TRANSIT pass files, as listed for unit 1;

Date	Time	Lat	Lon	End Time	End Lat	End Lon
09-20-89	01:39:40	47.6	1.1	01:49:15	64.4	-1.0
09-20-89	02:18:23	49.3	5.0	02:28:58	64.3	1.0
09-20-89	03:28:55	47.5	-16.7	03:40:10	67.1	-8.2
09-20-89	04:06:40	49.8	-11.1	04:21:15	74.5	-1.9
09-20-89	04:49:52	43.8	-2.4	05:00:27	63.0	-2.6
09-20-89	08:01:36	44.2	-5.3	08:17:51	76.4	-1.3
09-20-89	13:24:41	71.3	2.1	13:36:56	53.7	9.2
09-20-89	14:15:40	70.5	7.0	14:24:35	57.2	16.3
09-20-89	14:41:40	70.8	-3.3	14:56:15	47.1	-11.4
09-20-89	15:12:37	71.2	-1.8	15:26:32	50.7	-5.2
09-20-89	16:02:32	74.7	-0.3	16:11:47	58.7	1.6
09-20-89	17:01:20	70.4	-6.7	17:10:55	56.6	-18.0
09-20-89	17:27:00	70.6	5.6	17:37:35	52.7	15.8
09-20-89	17:52:32	72.2	-4.0	18:05:07	52.6	-12.9
09-20-89	19:15:40	70.4	-0.3	19:27:55	51.1	-0.3
09-20-89	21:04:13	71.8	-5.0	21:17:48	50.0	-17.1
09-21-89	01:16:12	46.3	4.3	01:24:52	60.9	0.9
09-21-89	03:06:59	50.5	-12.5	03:22:34	76.9	-0.9
09-21-89	06:17:24	47.5	-17.5	06:31:59	76.6	-1.5
09-21-89	07:10:21	69.2	7.2	07:20:16	54.4	17.5
09-21-89	07:39:53	48.1	-2.2	07:54:48	74.3	-1.6
09-21-89	09:54:19	53.1	-7.0	10:05:14	73.8	-3.7
09-21-89	12:29:40	70.9	2.5	12:42:35	49.6	8.7
09-21-89	14:17:54	72.5	-2.1	14:31:29	51.5	-7.1
09-21-89	17:29:20	72.5	-3.1	17:39:35	56.8	-8.1
09-22-89	00:54:40	50.0	6.4	01:08:35	75.0	-0.7
09-22-89	02:19:32	54.6	18.2	02:32:47	80.5	-9.7
09-22-89	02:43:00	48.3	-9.9	02:59:15	76.1	-1.7
09-22-89	05:54:04	46.9	-14.2	06:09:59	76.7	-1.4
09-22-89	07:15:56	45.5	1.0	07:26:51	64.3	-1.0
09-22-89	09:05:56	47.5	-17.2	09:17:31	68.8	-7.7
09-22-89	15:17:37	71.8	2.1	15:28:52	54.2	6.9
09-22-89	17:05:30	74.6	-1.9	17:20:45	47.2	-8.9
09-23-89	03:41:19	45.2	7.2	03:58:34	78.3	-1.8
09-23-89	05:08:40	55.8	17.5	05:20:55	77.7	-2.8
09-23-89	05:31:47	49.1	-10.4	05:41:02	63.3	-6.7
09-23-89	08:43:15	48.7	-13.4	08:58:30	76.7	-1.2
09-23-89	15:17:24	64.7	-3.2	15:27:39	51.3	-6.9
09-24-89	05:07:45	46.6	-7.7	05:24:40	76.8	-1.2
09-24-89	08:24:16	56.7	-8.2	08:35:51	75.8	-1.9
09-24-89	09:25:11	68.5	-1.2	09:37:26	50.8	-3.9
09-24-89	14:16:19	68.9	-7.3	14:25:34	55.7	-17.2
09-24-89	14:57:59	72.3	-4.1	15:12:14	49.2	-16.2
09-24-89	16:19:35	74.1	-1.0	16:33:30	51.1	-2.4
09-24-89	17:42:59	72.0	2.8	17:58:34	45.2	12.6
09-24-89	21:22:11	69.8	-8.1	21:31:06	57.0	-17.8
09-24-89	21:50:14	56.7	-4.9	22:03:09	77.8	-1.1
09-25-89	00:42:01	52.0	-4.1	00:56:16	74.6	-2.5
09-25-89	01:08:09	49.1	13.2	01:18:44	67.4	3.4
09-25-89	01:32:41	45.4	-0.9	01:48:56	75.4	-1.5

Table I. Summary Tabulation of TRANSIT Passes

Output:

Unit 2: direct-access TEC summary file, for TRANSIT and ETAC slant-path values;

Unit 10: (FOR010.DAT, if requested using LLTFIL) List of TRANSIT pass samples, with latitude, longitude, elevation, and vertical TEC;

Procedure:

Data base file handling:

1. If data base file is NEW, then open file and write header record, with number of data records initially zero; if data base file is OLD, then open file and read header record - if data base Site, SLat, or SLon do not match values provided by user, then print error message and terminate;
2. Define record number at which values will be added: (NRec + 1).

Data processing:

1. Accumulate 120 seconds (24 values) of TRANSIT data during a single pass (one TRANSIT file); (if fewer than 24 points are available at the end of a pass, then discard the segment.)
2. Compute an equivalent slant-path TEC for each vertical TRANSIT TEC value, referenced to the Ionospheric Penetration Point (IPP) as observed from specified Site (SLat, SLon);
   a. For initial points below 5° elevation, shift the starting time of the 120-second segment to the first value above 5°, and acquire new values to fill the segment;
   b. For trailing points below 5° elevation, discard the segment;
3. Compute mean vertical TRANSIT TEC for the 120-second interval, and standard deviation about this mean value;
4. Compute mean slant-path TRANSIT TEC for the 120-second interval;
5. Calculate the ETAC model slant-path TEC for the elevation and azimuth corresponding to the midpoint of the segment, using the average latitude and longitude of the two middle samples to compute the elevation and azimuth;
6. Calculate the time for the midpoint of the segment;
7. Store the values for the segment in the data base file;
8. Shift the last 12 values of the current segment to be the first 12 values of a new 120-second segment, and repeat the process from step 1;

9. At the end of the data processing, update the data base header for the final record count (NRec).

E. TRANSIT_ANALYSIS

The TRANSIT_ANALYSIS program generates a summary comparison plot of the TRANSIT and ETAC slant-path TEC values, using the direct-access database generated by TECSTAT as the source of the plotted values. The reference lines denoting relative error can be specified by the user, for up to six lines, and subsets of the data selected by elevation, azimuth, or local time can be plotted. The azimuth and local time variables are treated as cyclic quantities, so that selection ranges can be chosen which span the $180^{\circ}/-180^{\circ}$ or $24^{h}/00^{h}$ transitions by specifying the upper range limit value as a monotonic extension beyond 180° (up to 540°) for azimuths or beyond 24^{h} (up to 48^{h}) for local times.

Program: TRANSIT_ANALYSIS

Input:
- SYS$INPUT:
  - Namelist RELERR
    - FRACT = array of up to six values, for fractional error reference lines;
  - Namelist ERANGE
    - EMIN = lower limit for elevation range selection for TECSTAT data records (degrees);
    - EMAX = upper limit for elevation range selection for TECSTAT data records (degrees);
  - Namelist AZRANGE
    - AZMIN = lower limit for azimuth range selection for TECSTAT data records (degrees);
    - AZMAX = upper limit for azimuth range selection for TECSTAT data records (degrees);
  - Namelist TRANGE
    - TMIN = lower limit for local time range selection for TECSTAT data records (hours);
    - TMAX = upper limit for local time range selection for TECSTAT data records (hours);
  - IOUT = selection of plot format output option:
    - 0: TEKTRONIX terminal output;
    - 1: VT240 terminal output;
    - 2: DISSPOP metacode output (POPFIL.DAT);
    - 3: CGM binary output (CGMBOUT.DAT);
    - 4: CGM character output (CGMCOUT.DAT);

5: CGM clear text output (CGMTOUT.DAT);
Unit 1: (TECSTAT) TECSTAT database file;

Output:
Metacode file for DISSPLA metacode translator;

F. TECHIST

The TECHIST program tabulates and displays histograms of the relative ETAC model slant-path TEC deviation from the TRANSIT slant-path TEC values. Statistical binning is performed for elevation, azimuth, and local time ranges as well as for specified error ranges.

Program: TECHIST

Input:
SYS$INPUT:
CHOICE = selection of display option:
1: use newly specified bins;
2: use previously-generated bin tabulation;
Namelist BINDEF (required only for CHOICE = 1):
NEL = number of elevation bins specified (up to 10);
EL = thresholds for each elevation bin (degrees);
NAZ = number of azimuth bins (up to 10);
AZ = thresholds for each azimuth bin (degrees);
NTL = number of local time bins (up to 10);
TL = thresholds for each local time bin (hours);
ND = number of error bins (up to 20);
D = thresholds for each error bin (percent);
IOUT = selection of plot format output option:
0: TEKTRONIX terminal output;
1: VT240 terminal output;
2: DISSPOP metacode output (POPFIL.DAT);
3: CGM binary output (CGMBOUT.DAT);
4: CGM character output (CGMCOUT.DAT);
5: CGM clear text output (CGMTOUT.DAT);
Namelist PLOTDEF:
ELMIN = (1) starting bin index for elevation bins in histogram;
ELMAX = (NEL) ending bin index for elevation bins in histogram;
AZMIN = (1) starting bin index for azimuth bins in histogram;
AZMAX = (NAZ) ending bin index for azimuth bins in histogram;
TLMIN = (1) starting bin index for local time bins in histogram;

TLMAX = (NTL) ending bin index for local time bins in histogram;
YMAX = (-1.0) maximum value of ordinate for histogram, if auto-scaling is not selected;
AUTO_SCALE_OPT = selection of ordinate determination option:
Y: scale ordinate according to maximum data value;
N: scale ordinate according to "ceiling" values (0.045, 0.105);
Unit 1: (TECSTAT) TECSTAT database file;
Unit 3: (INBIN) (required only for CHOICE = 2) Previously-generated bin tabulation file;

Output:
SYS$OUTPUT: list of bin range definitions;
Unit 2: (OUTBIN) New bin tabulation file;
Metacode file for DISSPLA metacode translator;

G. TEC_UPDATE

The TEC_UPDATE program simulates the operational model-correction procedure, and generates a revised statistical database in the same format as the original TECSTAT database. The interval for allowing corrections by previous observations is provided by the user, with a default value of six hours.

Program: TEC_UPDATE

Input:
SYS$INPUT: Namelist SPECS
CRINT = critical interval for allowing corrections (hours);
Unit 1: (TECSTAT) TECSTAT database file;

Output:
Unit 2: (TECUPDAT) revised TECSTAT database file;

Procedure:
1. Use TECSTAT data sample time interval criteria to group TECSTAT records by pass:
If the time interval between successive records is less than 1.5 minutes, the records are part of same pass; if the time interval is greater than 1.5 minutes, a new pass has begun.
2. For TECSTAT values within a pass:
   a. Compute the ratio of the TRANSIT TEC value (T) to the ETAC model value (M) for each record:
   F = T/M
   b. Compute the average F for the pass (<F>);

c. Store this average value as the update factor.

3. Proceed to next pass. If the start of the pass is less than τ[a] after the end of the previous pass, then for each TECSTAT record in the pass:
   a. Save the original model value;[b]
   b. Compute an adjusted model value according to: M' = <F> * M
   c. Write the TECSTAT record with the adjusted model value to a new TECSTAT database.

   If the interval between passes is greater than τ, then proceed to step 4. (No records will be written to the new TECSTAT database for this pass.)
4. Use the original ETAC model values for each record to compute a new average update factor <F>.
5. Return to step 3.

a. The default value of τ is 6 hours, with provision to modify this value during processing.

b. There should be no more than 30 TEC statistics values for any single pass.

H. CODETEC

The CODETEC program generates a map of the TRANSIT pass coverage in latitude and local time, for the specified set of TRANSIT pass files. The longitude offset from the observer is incorporated as a local time correction in displaying the location of the TRANSIT pass measurements. A decimation factor can be specified to avoid plotting every TRANSIT measurement location, and allowing non-overlapping symbols on the plot.

Program: CODETEC

Input:
- SYS$INPUT: Namelist USRSPEC
  - FILEFILE = ('FILES.TEC') filename for the list of TRANSIT pass files to be plotted on map;
  - IDECIM = decimation factor for plotting of values along each TRANSIT pass;
  - OBSLON = local time reference longitude of observing site (degrees, positive East), for adjustment of local time of data;
- Unit 1: Individual TRANSIT pass files, as listed in file for unit 3;
- Unit 3: Number of TRANSIT pass files to be tabulated, and name of each file;

Output:
- Metacode file for NCAR metacode translator;

I. TRANSIT_TEC

The TRANSIT_TEC program generates a surface plot representation of the diurnal vertical TEC variation, based on the TRANSIT pass data for a given day. The independent variables for this representation are considered to be local time and magnetic latitude, rather than geographic latitude. As with the geographic mapping of the passes, a correction is incorporated for the displacement in longitude of the TRANSIT reference point with respect to the observing site. Provisions for decimating the TRANSIT pass data along the direction of the pass are also included, with a minimum decimation factor of five utilized to reduce storage requirements within the program.

The TEC values are interpolated to generate surface values, but large gaps in local time tend to produce irregular effects, so a TRANSIT pass coverage map (CODETEC) should first be examined to determine suitable days for TEC surface plot representations. Three views of the surface are standardly generated, with the viewing angles either defaulting to a standard set or being specified by the user.

Program: TRANSIT_TEC

Input:

SYS$INPUT: Namelist SPECS

- NUM_FILES = number of TRANSIT pass files to be incorporated into the surface plot;
- FILENAME = array of up to 18 filenames designating TRANSIT passes (up to 40 characters per filename);
- SITE = four-character observing site designation;
- OBSLAT = latitude of observing site (degrees North);
- OBSLON = local time reference longitude of observing site (degrees East);
- DECIMATION = integer decimation factor for each pass;
- DELTA_TIME = (5.0) time interval between TRANSIT data samples (seconds)

Namelist EYE

- ELEV = array of three elevation angles for the viewing directions (degrees);
- AZIM = array of three azimuthal angles specifying the viewing directions (degrees);
- ANG = array of three tilt angles specifying the viewing orientation (degrees);

Unit 33: Individual TRANSIT pass files, as listed in the FILENAME array;

Output:
    Metacode file for DISSPLA metacode translator;

References

1. Llewellyn, S.K., and Bent, R.B. (1973) Documentation and Description of the Bent Ionospheric Model, AFCRL-TR-73-0657, AD772733